# Private Crop Insurers and the Reinsurance Fund Allocation Decision

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This research investigates the strategic behavior of private crop insurance firms reinsured by the USDA through the Standard Reinsurance Agreement. This arrangement allows the private firm to strategically allocate individual policies into different risk-sharing arrangements. Thus, firm earnings are conditioned upon accurately forecasting policy loss experience. Our analysis begins with models investigating the characteristics explaining the placement of policies into the assigned risk fund. Then a simulation model of the SRA is used to compare the post-SRA returns of actual firm allocations to two alternative allocation strategies based on a aggregate models and a policy-level econometric forecasting model.

*Key words*: insurance, out-of-sample forecasting, policy, risk.

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A unique aspect of the federal crop insurance program since passage of the Federal Crop Insurance Act of 1980 has been the role of private insurance companies in program delivery and risk sharing (Glauber and Collins 2002). Unlike other federal insurance programs (e.g., flood insurance), private insurance companies not only sell and service crop insurance policies but also annually share with the federal government underwriting risks on over $45 billion of liability.

Because of the wide disparity in underwriting gains across regions and crops (Vedenov et al. 2004), a problem facing the federal crop insurance program has been how to encourage companies to deliver insurance policies in areas where expected gains are low or exposure is high. To encourage the provision of federal crop insurance to all eligible producers, the government shares risks with companies through the Standard Reinsurance Agreement (SRA) (USDA-RMA 1998, 2005). Under the SRA, if a company elects to write crop insurance policies in a state it must offer coverage to any farmer in that state. In addition, it must accept the rates and underwriting provisions set by the Federal Crop Insurance Corporation (FCIC). In exchange, the company is allowed to place some crop insurance policies in an Assigned Risk Fund where its exposure is minimal and to place other policies in funds where potential underwriting gains and losses are greater.

While much has been written on the federal crop insurance program (see reviews by Goodwin and Smith 1995, Knight and Coble 1997, and Glauber 2004), little research has appeared on the SRA. Notable exceptions include simulations of the SRA by Miranda and Glauber (1997), Mason, Hayes, and Lence (2003), and Vedenov et al. (2004). These works have developed large-scale stochastic simulations to investigate potential changes in the structure of the SRA given an assumed fund allocation of the firm. In addition, Vedenov et al. (2006) used a simulation model based on representative insurance contracts to examine possible reinsurance allocations under alternative SRA specifications. Ker and McGowan (2000) modeled the potential for companies to use El Nino/La Nina information to earn economic rents from the SRA reinsuring an area yield design. More recently, Ker and Ergün (forthcoming) made an important step toward understanding actual insurance firm allocations and through out-of-sample testing found evidence that firms have significant private information. However, their analysis used data aggregated to the county level and did not allow for examination of individual policies attributes or individual company behavior.

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In contrast, we examine policy-level allocation decisions made by individual crop insurance companies, analyzing firm-level reinsurance fund allocations made over 1998–2003. Using a logit model, we examine the characteristics of over 2 million individual crop insurance policies to identify the factors influencing the allocation of policies to the Assigned Risk Fund and how these factors differ across companies. We then examine the allocation decisions of crop insurance firms and compare their actual post-SRA gains to those of a simple county-level allocation system and to those based on an econometric model. The results show that firms are not equally effective in allocating policies to the Assigned Risk Fund. Although, in aggregate, firms are more effective in their actual allocations of policies than they would be if the simple county-level decision rule were used, allocations based on an out-of-sample econometric model forecasts generally result in greater underwriting gains than actual allocations.

## Conceptual Framework

The terms under which private companies sell, service, and underwrite federal crop insurance are specified in the SRA, which is negotiated from time to time by the companies and the federal government. Our analysis is based on the 1998 SRA (USDA-RMA 1998), the SRA that was in effect with minor modifications from 1998 through 2004, the time period for which data on individual policy allocations were available. Based on Vedenov et al. (2006) the relatively minor changes in the more recent SRA would not change the implications of the analysis.

Under the SRA, companies retain risks, or alternatively cede risks to FCIC, by designating individual crop insurance policies to reinsurance funds. Different parameters of each of the funds allow a company to retain or cede different proportions of premium and associated liability (proportional reinsurance) and to share with FCIC different amounts of the eventual underwriting gains or losses on retained premium and liability (nonproportional reinsurance). The levels of retention and of potential gains and losses to a company are highest on policies placed in commercial funds (three funds, each for a different type of insurance coverage) and lowest on policies placed in the Assigned Risk Fund. Intermediate levels of retention and gain and loss sharing are available in developmental funds. In the Assigned Risk Fund, 80% of the premium and associated liability is ceded to FCIC; the company retains 20%. Under the developmental fund, companies must retain at least 35% (and may retain up to 100%) of the premium and associated liability; under the commercial fund, companies must retain a minimum of 50% (and may retain up to 100%) of the premium and associated liability. Of the liability retained by the company, FCIC pays increasing shares of the indemnities, depending on the company's state-level loss ratio (indemnities divided by total premium) in the fund, with FCIC paying the entire loss as the loss ratio exceeds 5.0.

Shares of gains and losses that fall to the private insurance companies differ markedly by fund (table 1). For example, the maximum possible underwriting loss on Assigned Risk policies is 11% of company-retained premium. The company's potential for underwriting gains on policies placed in the Assigned Risk Fund, however, is also small: maximum of 7.6% of retained premium. In contrast, companies can gain as much as 48.9% of retained premium for policies in the commercial fund. However, the downside risks are larger as well. The maximum possible underwriting loss on policies placed in the commercial fund is 107.6% of retained premium.

Companies designate policies to the reinsurance funds within thirty days of the crop insurance sales closing dates. In general this puts the allocation deadline slightly before planting. Insurance companies may use information available at that time to decide how much risk on which policies to retain or to cede. While limited information is available regarding prospective growing conditions, companies have access to a great deal of information regarding the insurance policy, including past experience.

The fund designation decision can be characterized by the information sets used by FCIC and the company to determine the actuarial soundness of an insurance policy, that is, the relationship between total premium (producer-paid premium plus premium subsidy), $\prod$, and the expected indemnity E(I). The FCIC uses an insurance premium rating system that is largely based on historical loss experience in a county for a particular crop and adjusted to policy specific characteristics. The FCIC, the government, G, assumes the expected indemnity is equal to premium resulting from these rate factors. Premiums are conditioned on crop

**Table 1. Shares of Underwriting Gains and Losses to Insurance Companies under the 1998 Standard Reinsurance Agreement**

| | | Reinsurance Fund | | | | | |
|---|---|---|---|---|---|---|---|
| | | Developmental | | | Commercial | | |
| Loss Ratio | Assigned Risk | CAT | Revenue | All Other | CAT | Revenue | All Other |
| | | Percentage of Loss/Gain | | | | | |
| Losses | | | | | | | |
| 1.0–1.6 | 5.0 | 25.0 | 30.0 | 25.0 | 50.0 | 57.0 | 50.0 |
| 1.6–2.2 | 4.0 | 20.0 | 22.5 | 20.0 | 40.0 | 43.0 | 40.0 |
| 2.2–5.0 | 2.0 | 11.0 | 11.0 | 11.0 | 17.0 | 17.0 | 17.0 |
| >5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Gains | | | | | | | |
| 0.65–1.0 | 15.0 | 45.0 | 60.0 | 60.0 | 75.0 | 94.0 | 94.0 |
| 0.5–0.65 | 9.0 | 30.0 | 50.0 | 50.0 | 50.0 | 70.0 | 70.0 |
| <0.5 | 2.0 | 4.0 | 6.0 | 6.0 | 8.0 | 11.0 | 11.0 |

Note: Share of loss or gain is determined incrementally by the realized loss ratio for a company's business in each state and fund.

price, $P_g$, coverage level, $C_i$, actual production history or APH yield, $\bar{Y}_i$, number of acres insured, $A_i$, and premium rate, $R$. The premium rate, in turn, depends on the insurance type (one of several revenue and yield insurance plans), $T_i$, the crop insured, $K_i$, coverage level, $C_i$, the APH yield, the base county yield, $\tilde{Y}_i$, the number of actual yields in the APH, $N_i$, unit selection (whether a policy's acreage is subdivided into optional units), $U_i$, and the specific crop type and practice, $P_i$. The expected indemnity for the Government is summarized as follows:

$$E(\mathrm{I} \mid G) = \Pi(P_g, C_i, \bar{Y}_i, A_i, R(T_i, K_i, C_i, \bar{Y}_i, \tilde{Y}_i, N_i, U_i, P_i)). \tag{1}$$

The insurance firm is concerned with the net return of the policy, $NR_i = (\Pi - E(I))$, which is driven by the perceived accuracy of the rating factors and other information about the policy. In particular, the insurance firm can utilize information from past participation, underwriting experience, and early season growing conditions to adjust expectations of the net returns. Thus, we write the insurance firm's expectation of net return $E(NR \mid F)$ as a function of the policy characteristics from equation (1) and add the firm's information set, $F$, which includes the firm's knowledge of historical loss ratios for the policy relative to peers, $\mathrm{FI}_i$, the policy's continuous participation in the insurance program, $FC_i$, and year-specific early season growing conditions, $FY_i$.

$$E(NR \mid F) = NR(P_g, C_i, \bar{Y}_i, A_i, R(T_i, K_i, C_i, \bar{Y}_i, \tilde{Y}_i, N_i, U_i, P_i), FI_i, FC_i, FY_i). \tag{2}$$

Having defined the firm's expectation of the net return to the insurance policy, the policy allocation decision may be written as follows:

$$\underset{\delta_i}{\mathrm{Max}}\, L = EU\left\{\sum_{i=1}^{N} \Gamma(\delta_i) NR(\bullet \mid F)\right\} \text{ s.t. } \sum_{i=1}^{N} \delta_i \Pi(\bullet \mid G) < S \tag{3}$$

where $\delta$ is an indicator variable that represents the insurance firm's choice of which reinsurance fund to allocate the $i$th policy. The variable $\Gamma$ is a function of $\delta$, and represents the proportional share of premiums and indemnities retained by the crop insurance firm given the allocation of a policy to the $i$th fund.

We couch the firm's decision in an expected utility framework where the private crop insurance firm is potentially risk averse and desires the risk reduction of the SRA. Thus, the risk context of the firm would also affect the decision to allocate policies to the Assigned Risk Fund. We characterize the risk context of the firm's crop insurance business by considering

its effective premium rate, $EPR_F$, which reflects the riskiness of the company's book of business. Geographic concentration across states, $CR_F$, provides a measure of the insurance firm's portfolio diversification. We also include the number of policies sold within a state, $PC_F$, which is hypothesized to have a positive relationship with the effort a firm might expend to select policies for the Assigned Risk Fund. Finally, we add the state-by-state constraints on the percentage of premium the firm can cede under terms of the SRA, S.

In summary, we hypothesize that the insurance company's fund allocation decisions are affected by the company's portfolio and risk position along with the characteristics of the individual policies. This is shown in equation (4).

$$\delta_i = f[EPR_F, CR_F, PC_F, \mathrm{S}, NR(P_g, C_i, \bar{Y}_i, A_i, R(T_i, K_i, C_i, \bar{Y}_i, \tilde{Y}_i, N_i, U_i, P_i, FI_i, FC_i, FY_i))]. \tag{4}$$

## Logit Model

A logit model consistent with equation (4) was specified to predict the allocation of crop insurance policies to the Assigned Risk Fund. We used insurance policy level records obtained from the Risk Management Agency (RMA) of the U.S. Department of Agriculture, which administers the crop insurance program. These data report characteristics of policies insured between 1994 and 2003 and the reinsurance fund designation for each policy for 1998 through 2003. Because the data for early years do not distinguish between commercial and developmental funds we simplified the firm's choice to one of the placements in the Assigned Risk Fund or not.

The underlying RMA data are at the unit, or sub-policy, level. They identify the crop types and practices used on the unit, the unit breakout within the policy, the yield histories, and actual loss experience on each unit. Although insurance indemnities are calculated and paid at the unit level, the Assigned Risk designation is made on a policy-by-policy basis. Therefore, we aggregated the data, weighted by the amount of liability, from the unit to the policy level. Once the data for a particular year were aggregated to the policy level, then a search, by the tax identification number of the policy, was conducted across the four prior years to find whether the policy had been in the crop insurance program. The record for the policy was then used to calculate a historical loss ratio for the policy, which was attached to the data in the year in which the policy was insured. Data were available from all states for the four top crops in the U.S. crop insurance program: corn, soybeans, wheat, and cotton.

The variables in the logit model and their summary statistics are listed in table 2. Variables that represent the risk context of the insurance company's book of crop insurance business are listed first. The effective premium rate for the company is a measure of the riskiness of its crop insurance business in a state and year. It is calculated by summing the premiums and liabilities of policies written by the company and dividing total premium by liability. The concentration ratio indicates the diversification of a company's crop insurance portfolio across states in a particular year. The ratio, which is similar to the Herfindahl–Hirschman index used to measure market concentration, is the summation of the squared shares of total premium for a company's crop insurance business in each of the states. If a company operates in only one state, the ratio has the value of 1. The policy count variable measures the size of the company's business in a state and the number of decisions the company may make on whether to use the Assigned Risk Fund. The cession limits, which are negotiated by the companies and FCIC and are known prior to the fund designation decisions, are the maximum proportion of a company's crop insurance business in a state that can be placed in Assigned Risk. The limits are listed in the SRA and range from 10% to 75% of a company's total premium in a state.

The next section of table 2 lists variables that are characteristics of the particular insurance policies. The effective premium rate for a policy is constructed by dividing the sum (over the units in the policy) of total premium by liability. The loss ratio index is the loss ratio for the policy during the previous four years divided by the loss ratio for all policies in the same county during the same period. It measures the loss ratio for a particular producer relative to a peer group of producers producing the same crop in the same county (Rejesus et al. 2006).[1] The county loss ratio variable is the ten-year average loss ratio for the crop in

[1] The use of a four-year historical index omits farms with shorter histories from the analysis. Thus, the analysis may not be representative of the SRA treatment of newer participants.

**Table 2. Summary Statistics of Explanatory Variables in Logit Model of Policy Designation, by Fund Designation**

| | Assigned Risk | | | Not Assigned Risk | | |
|---|---|---|---|---|---|---|
| Variable | Mean | Standard Deviation | Range | Mean | Standard Deviation | Range |
| Company characteristics/risk context | | | | | | |
| Effective premium rate-company | 0.097 | 0.030 | 0.974 | 0.081 | 0.025 | 0.526 |
| Geographic concentration ratio | 0.143 | 0.173 | 0.945 | 0.134 | 0.174 | 0.945 |
| Policy count | 4,157 | 3,640 | 24,418 | 6,196 | 5,492 | 24,418 |
| Cession limit | 0.331 | 0.185 | 0.650 | 0.244 | 0.125 | 0.650 |
| Policy characteristics | | | | | | |
| Effective premium rate-policy | 0.124 | 0.079 | 0.994 | 0.078 | 0.052 | 0.993 |
| Loss ratio index | 1.254 | 2.434 | 428.29 | 0.748 | 2.106 | 668.572 |
| County loss ratio | 1.039 | 0.602 | 8.72 | 0.673 | 0.425 | 6.968 |
| Number of actual yields | 7.195 | 2.602 | 10.0 | 7.604 | 2.466 | 10.0 |
| Yield span | 1.198 | 0.255 | 9.485 | 1.219 | 0.218 | 15.153 |
| Coverage level | 69.067 | 7.398 | 35.0 | 66.341 | 8.986 | 35.0 |
| Net acres insured | 260.64 | 408.91 | 31,134 | 182.10 | 270.84 | 28,514 |
| Years of continuous participation | 6.027 | 1.528 | 5.0 | 5.942 | 1.530 | 5.0 |
| CAT coverage | 0.027 | 0.161 | 1 | 0.099 | 0.299 | 1 |
| Insurance plan | | | | | | |
| Crop revenue coverage (CRC) | 0.409 | 0.492 | 1 | 0.282 | 0.450 | 1 |
| Revenue assurance (RA) | 0.146 | 0.353 | 1 | 0.116 | 0.320 | 1 |
| Income protection (IP) | 0.003 | 0.058 | 1 | 0.011 | 0.104 | 1 |
| Crop | | | | | | |
| Soybeans | 0.256 | 0.437 | 1 | 0.389 | 0.488 | 1 |
| Wheat | 0.476 | 0.499 | 1 | 0.215 | 0.411 | 1 |
| Cotton | 0.012 | 0.109 | 1 | 0.006 | 0.076 | 1 |
| Year | | | | | | |
| 1998 | 0.041 | 0.198 | 1 | 0.100 | 0.300 | 1 |
| 1999 | 0.194 | 0.395 | 1 | 0.159 | 0.365 | 1 |
| 2000 | 0.206 | 0.404 | 1 | 0.160 | 0.367 | 1 |
| 2001 | 0.156 | 0.363 | 1 | 0.173 | 0.379 | 1 |
| 2002 | 0.154 | 0.361 | 1 | 0.194 | 0.395 | 1 |

Note: Number of observations in Assigned Risk = 250,381; not in Assigned Risk = 1,911,584.

the county. It indicates the actuarial soundness of the county-crop insurance combination.

The next variable listed is the number of APH yields used to establish the insurance coverage of the policy. Because of aggregation across units, this variable is the average number of historical yields for the units within the policy. For example, a policy might have, on average, four-and-a-half years of actual yields in the yield history. The yield span variable is the average APH yield for the units within the policy divided by the county reference yield. For example, if the average APH yield on a particular farm was 150 bushels for corn and the county reference yield was 100 bushels, then the yield span would take a value of 1.5. The yield span indicates whether the mean yields for a particular farm are above or below those of a peer group. Under current rating practices, farms with lower yield spans receive an exponentially higher rate than that charged when the APH yield is at the county reference yield (Skees and Reed 1986).

Coverage level is the proportion of expected yield or revenue insured. The crop insurance program allows producers to choose from coverage levels that range from 50% to 85%. Higher coverage levels suggest a greater level of risk to the insurer because it is plausible that there would be a greater degree of moral hazard when the deductible is reduced. Net acres insured is the number of acres covered by the policy, weighted by the ownership share of the policyholder. The weighting avoids double counting of acres when both tenant and landlord insure the same acres under separate policies. The variable "years of continuous participation" is the number of consecutive years, since 1994, during which the policy has been in effect.

Crop insurance policies are characterized in the model by the type of insurance: yield insurance at the lowest, catastrophic (CAT) coverage level or at a higher, "buy up" coverage level, or one of several types of revenue insurance. To test whether designation of an insurance policy to the Assigned Risk Fund depends on the type of insurance, we constructed a set of indicator variables with a non-CAT yield insurance policy as the default case. The CAT indicator variable has a value of 1 if the policy is at the minimal coverage level. The crop revenue coverage (CRC) variable indicates that the policy is a revenue insurance coverage that can increase if crop price increases. Revenue Assurance (RA), during the period analyzed, is a type of revenue insurance without potentially increasing coverage. Income Protection (IP) is revenue coverage similar to RA, except that the policy cannot be divided into separately insured optional units. Finally, we included crop and year dummy variables to distinguish the crop insured—corn, wheat, cotton, or soybeans—and to capture the year-specific events.

The possibility that pre-season weather may influence the fund allocation decision was considered. It is difficult to measure what weather information the firms have at the time the allocation decision must be made. Weather data such as monthly rainfall and temperature and subsoil moisture levels are available, but previous empirical work suggests that their influence on crop growth varies widely by crop and region and in many cases show poor correlation (Luo, Skees, and Marchant 1994). Moreover, if pre-planting weather is poor then it is likely to translate into a prevented planting or replant claim against the insurance policy. Of the data in our analysis, 6.26% of the policies had a prevented planting or replant claim. Less than 20% of those claims were on policies placed in the Assigned Risk Fund. We also looked at the incidence of policies migrating in or out of the Assigned Risk Fund. Over the period examined a policy stayed in the same category as the previous year 89% of the time. This suggests a limited ability to predict losses that occur very near the SRA assignment date as opposed to losses occurring several months later. To the extent that companies use early season weather information to shift policies in a particular year, this variation may be captured in the annual dummy variables.

Table 3 shows the results of the logit model of whether a crop insurance policy was designated to the Assigned Risk Fund.[2] Given the large sample size and the many degrees of freedom, every explanatory variable is significant at the 0.001 level. The model concordance is 79.7%. This means that, given a pair of policies, one in Assigned Risk and one not in Assigned Risk, the model predicted a higher probability of being placed in Assigned Risk for the policy that was actually placed in Assigned Risk.

Results for the company characteristics show that the effective premium rate of a company's crop insurance business has a positive relationship with placement of a particular policy in the Assigned Risk Fund. The geographic concentration ratio also has a positive relationship with designation to the Assigned Risk Fund. However, as the number of policies a company has in an individual state increases, the less likely it is to place a policy in the Assigned Risk Fund. The state-level cession limit, the percentage of premium and associated liability that can be placed in Assigned Risk Fund, has a positive relationship with whether policies are designated to Assigned Risk. Because the companies and FCIC negotiate the SRA cession limits, there is an incentive for the companies to press for higher limits for states where they expect to place greater shares of their business in the Assigned Risk Fund. Thus, it is not surprising that there is a positive statistical relationship between the limits and companies' allocation of policies to Assigned Risk.

The remaining variables in table 3 are for individual policy characteristics. The effective premium rate for a policy has a positive relationship with designation to the Assigned Risk Fund. In other words, policies that are deemed riskier based on the rates charged are more likely to be designated to Assigned Risk. The loss ratio index, which compares the individual policy to peers, has a positive relationship with placement in the Assigned Risk Fund. This suggests that firms consider the historical experience of individual policies in choosing whether to designate them to Assigned Risk. As expected, the number of actual yields in the yield history has a negative relationship with whether the policy is in Assigned Risk. The greater the number of actual yields, the more confident of the accuracy of the history an insurer might be. Similarly, the results

[2] A probit model gives identical sign and significance on all variables except for years of continuous participation.

**Table 3. Logit Model Results of Designation of Crop Insurance Policies to Assigned Risk Fund**

| | Industry-level | | | | Firm-level Signs and Significance of Estimates | | |
|---|---|---|---|---|---|---|---|
| Variable | Estimate | Standard Error | Pr > Chi Square | Marginal effect | Positive and Significant | Negative and Significant | Not Significant |
| | | | | | Number of Estimates | | |
| Intercept | −7.2916 | 0.0384 | <0.0001 | — | 2 | 14 | 1 |
| Company characteristics/risk context | | | | | | | |
| Effective premium rate-company | 4.7947 | 0.1340 | <0.0001 | 0.4129 | 11 | 4 | 2 |
| Geographic concentration ratio | 1.2502 | 0.0133 | <0.0001 | 0.1077 | 6 | 7 | 4 |
| Policy count | −0.0001 | <0.0001 | <0.0001 | <−0.0001 | 2 | 12 | 3 |
| Cession limit | 0.7610 | 0.0195 | <0.0001 | 0.0655 | 10 | 3 | 4 |
| Policy characteristics | | | | | | | |
| Effective premium rate-policy | 4.6463 | 0.0441 | <0.0001 | 0.4001 | 17 | 0 | 0 |
| Loss ratio index | 0.0806 | 0.0010 | <0.0001 | 0.0069 | 17 | 0 | 0 |
| County loss ratio | 0.8948 | 0.0049 | <0.0001 | 0.0771 | 16 | 0 | 1 |
| Number of actual yields | −0.0240 | 0.0010 | <0.0001 | −0.0021 | 1 | 15 | 1 |
| Yield span | 0.1886 | 0.0110 | <0.0001 | 0.0162 | 10 | 6 | 1 |
| Coverage level | 0.0443 | 0.0004 | <0.0001 | 0.0038 | 14 | 2 | 1 |
| Net acres insured | 0.0001 | <0.0001 | <0.0001 | <0.0001 | 14 | 2 | 1 |
| Years of continuous participation | −0.0079 | 0.0024 | 0.001 | −0.0007 | 6 | 5 | 6 |
| CAT coverage | −0.7060 | 0.0149 | <0.0001 | −0.0608 | 3 | 11 | 3 |
| Insurance plan | | | | | | | |
| Crop revenue coverage (CRC) | 0.3241 | 0.0055 | <0.0001 | 0.0279 | 10 | 5 | 2 |
| Revenue assurance (RA) | 0.3133 | 0.0082 | <0.0001 | 0.0270 | 9 | 4 | 4 |
| Income protection (IP) | −0.4941 | 0.0366 | <0.0001 | −0.0426 | 2 | 6 | 9 |
| Crop | | | | | | | |
| Soybeans | 0.2000 | 0.0062 | <0.0001 | 0.0172 | 13 | 1 | 3 |
| Wheat | 0.5982 | 0.0064 | <0.0001 | 0.0515 | 14 | 2 | 1 |
| Cotton | 0.0216 | 0.0241 | 0.3702 | 0.0019 | 6 | 5 | 6 |
| Year | | | | | | | |
| 1998 | −0.9471 | 0.0152 | <0.0001 | −0.0816 | 2 | 10 | 5 |
| 1999 | 0.4493 | 0.0105 | <0.0001 | 0.03870 | 5 | 7 | 5 |
| 2000 | 0.4271 | 0.0093 | <0.0001 | 0.0368 | 9 | 5 | 3 |
| 2001 | −0.1508 | 0.0085 | <0.0001 | −0.0130 | 8 | 7 | 2 |
| 2002 | −0.2761 | 0.0078 | <0.0001 | −0.0238 | 5 | 3 | 9 |

Note: Model fit at the industry-level: Percent Concordant = 79.7; Percent Discordant = 19.8; Percent Tied = 0.4. Significance in firm-level models is measured at 0.10 level.

show that the number of years of continuous participation is negative and significant. The longer the experience with a policy, the less likely it is to be in Assigned Risk.

The yield span variable has a positive relationship with designation to Assigned Risk. This indicates that where the average APH yield is greater than the county reference yield the policy is more likely to be placed in the Assigned Risk Fund. This suggests that, under the rating system, insurers judge insurance policies for low yielding farms as more likely to produce an underwriting gain. The number of acres (net acres) covered by a policy has a positive and statistically significant relationship with placement in the Assigned Risk Fund.

Coverage level, the percentage of expected yield or revenue that is insured, is positively related with allocation to the Assigned Risk Fund. The higher the coverage level, the more likely it is that policies will be placed in Assigned Risk. This suggests that crop insurance companies do not perceive coverage levels to be equally actuarially sound, which may stem from perceptions that policies with lower deductibles are more prone to moral hazard problems.

The indicator variables of type of insurance show that CAT policies, which insure 50% of expected yield at 55% of expected price, were significantly less likely to be placed in the Assigned Risk Fund. CRC and the RA policies are more likely and IP policies are less likely, relative to APH yield insurance policies, to be placed in Assigned Risk. The crop variables show that cotton and wheat policies are more likely and soybean policies are less likely than corn policies to be in Assigned Risk. The year variables, all of which were significant, indicate that, relative to 2003, policies in 1999 and 2000 were more likely to be placed in Assigned Risk while policies in 1998, 2001, and 2002 were less likely to be placed in Assigned Risk.

The logit model was also estimated separately for each of the companies in the crop insurance program for all six years from 1998 to 2003.[3] The variables included in the firm-level estimates are the same as those of the industry-level. The values of the company characteristic variables (effective premium rate for a company, geographic concentration ratio, policy count, and cession limit) are the same for a given company for a given year. Any variation in these variables thus reflects changes in a company's mix of business from year to year.

The signs and statistical significance of the firm-level results are summarized in the right-hand side of table 3.[4] In the company models, most of the policy variables were strongly significant and consistent with the aggregate model. For example, estimated coefficients for the effective policy premium rate, the loss ratio index, and the county loss ratio were largely positive and significant. These results are consistent with the strong marginal effects observed in the aggregate model. The number of actual yields is also consistent across firm level models. In fifteen of the seventeen firms, it has a negative and significant effect. In only one firm was there a positive effect. The yield span variable is positive and significant in the aggregate model and it remains positive and significant in ten of the seventeen firm level models. Of the remaining variables, there was less agreement in signs across firms. Most of the differences can be explained by the fact that many of the variables were related to the various regions in which the companies concentrate their business. For example, a number of companies concentrate their business in Midwestern states where few, if any, cotton policies are sold.

## Effects of the Allocation Decisions on Underwriting Gains

Given evidence that the characteristics of the firm, of the SRA, and of the individual policy are explanatory variables predicting whether policies are placed in Assigned Risk, what are the economic consequences of the allocation? In general, firms have been able to cede policies with underwriting losses to the government by placing them in the Assigned Risk Fund while they retain policies with underwriting gains. From 1992 to 2003, the loss ratio for policies placed in the Assigned Risk Fund exceeded the loss ratio for policies placed in commercial funds in all years but one (Glauber 2004). For the policies in our study, the loss ratio for the years 1998–2003 for the policies that were placed in the Assigned Risk Fund exceeded the loss ratio for policies that were not placed in the Assigned Risk Fund. Policies with

[3] Likelihood ratio tests reject a pooled model.

[4] Seventeen firms operated in all six years of the study period.

about $875 million in premiums were placed in Assigned Risk Fund; about $1.075 billion in indemnities was paid on these policies, resulting in a loss ratio for the Assigned Risk policies of 1.20. In contrast, the loss ratio for non-Assigned Risk policies was near 0.79 ($2.97 billion in indemnities divided by $3.77 billion in premium).

But how effective have the crop insurance companies been in allocating policies? Was the actual allocation used the most efficient allocation for the crop insurance companies under the terms of the 1998 SRA? Two alternative approaches to the insurance company's actual allocation were investigated. One uses a naïve rule that allocates policies based on the historical loss ratio for the county; the other allocates policies based on a Tobit model that predicts the loss ratio for individual policies.

To conduct the comparisons, we randomly classified one-half of the data (annual observations of insurance policies) from 1998 to 2003 period as in-sample observations. These data were used to allocate policies to reinsurance funds. We then used the other half of the data as out-of-sample observations in order to evaluate the effectiveness of the allocations. This allowed us to use data from as many years as possible to measure the actuarial experience of the policies.

Under the naïve approach, the historical loss ratio for each of the counties within a state was calculated from 1981 through the prior year. Counties within the state were ranked from high to low based on their aggregate historical loss ratio. In-sample policies were then placed into the Assigned Risk Fund on a county-by-county basis beginning with the county with highest loss ratio and continuing until the county loss ratio fell below a selected cutoff point or the state Assigned Risk cession limit was reached.

The policy-level approach uses an econometric model to predict the loss ratio for each individual policy. In a similar manner to the above, policies were ranked within a state from high to low based on their expected loss ratio. Policies were then placed into the Assigned Risk Fund beginning with the policy with the highest expected loss ratio and continuing until the policy expected loss ratio fell below a cutoff point or the state Assigned Risk cession limit was reached.

Under the county-level approach and the policy-level approach optimal cutoff points were selected using grid searches. Post-SRA

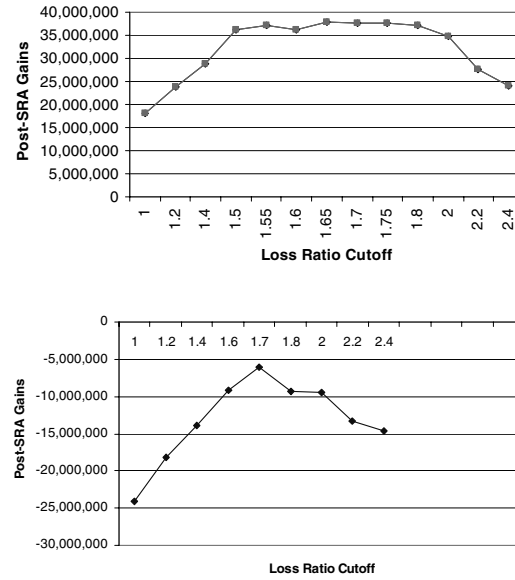


**Figure 1. (a) Model-based returns for alternative decisions rule. (b) County-based returns for alternative decision rules**

returns were estimated given 0.025 loss ratio intervals between 1.0 and 2.0. The results are presented in figures 1a and 1b. While the optimal cutoff points, the loss ratio cutoffs for placing policies in the Assigned Risk Fund, are similar across the two approaches, 1.65 for the policy-level and 1.70 for the county-level, there are several differences. First, the y-axis scale indicates that the policy-level model tends to generate post-SRA underwriting gains while the county-based model never achieves a breakeven level. These results imply that the policy model results in allocations of policies such that post-SRA earnings exceed pre-SRA levels. The results for the county model suggests that given the years examined here, the county model never allocates policies into the SRA well enough to result in greater post-SRA earning than pre-SRA earnings. Also, the policy-level returns have a fairly flat curve with relatively little difference between cutoffs of 1.5 to 1.8. For the county-level returns movement away from 1.7 tends to sharply reduce returns. We would expect a cutoff point above 1.0 because of the structure of the SRA: asymmetry of loss and gain sharing and stop-loss protection. Vedenov et al. (2006), working with a simulation model that used a longer time series, found an optimal cutoff point of around 1.125. Sensitivity analysis to the particular years used in our analysis

**Table 4. Tobit Model of Crop Insurance Policy Loss Ratio**

| Variable | Estimate | Standard Error | Pr > Chi Square | Marginal Effect |
|---|---|---|---|---|
| Intercept | −12.7355 | 0.0791 | <0.0001 | — |
| Risk context | | | | |
| Cession limit | 2.3038 | 0.0516 | <0.0001 | 0.5637 |
| Policy characteristics | | | | |
| Effective premium rate-policy | 15.2159 | 0.1207 | <0.0001 | 3.7233 |
| Loss ratio index | 0.1648 | 0.0023 | <0.0001 | 0.0403 |
| County loss ratio | 0.2898 | 0.0150 | <0.0001 | 0.0709 |
| Number of actual yields | −0.1976 | 0.0026 | <0.0001 | −0.0484 |
| Yield span | 1.7530 | 0.0297 | <0.0001 | 0.3006 |
| Coverage level | 0.0616 | 0.0009 | <0.0001 | 0.0151 |
| Net acres insured | 0.0012 | 0.0000 | <0.0001 | 0.0003 |
| Years of continuous participation | 0.2842 | 0.0044 | <0.0001 | 0.0695 |
| CAT coverage | −1.5769 | 0.0327 | <0.0001 | −0.3859 |
| Insurance Plan | | | | |
| Crop revenue coverage (CRC) | 0.5115 | 0.0147 | <0.0001 | 0.1252 |
| Revenue assurance (RA) | 0.0668 | 0.0207 | 0.0013 | 0.0163 |
| Income protection (IP) | −2.3188 | 0.0842 | <0.0001 | −0.5674 |
| Crop | | | | |
| Soybeans | 0.7902 | 0.0145 | <0.0001 | 0.1934 |
| Wheat | 0.1638 | 0.0178 | <0.0001 | 0.0401 |
| Cotton | −0.2930 | 0.0732 | <0.0001 | −0.0717 |
| Scale | 4.7682 | 0.0072 | — | — |

Note: Number of observations = 1,080,714; Noncensored values = 285,266; Right censored values = 0; Left censored values = 795,448; Interval censored values = 0; Log likelihood = −1,154,572.961

suggests that the optimal cutoff is conditional upon the presence of high loss ratio years.[5]

The econometric model of predicted loss ratio uses the same insurance policy characteristic variables of that were used in logit model. A Tobit model was selected to account for censoring of the loss ratio at zero. The firm characteristic variables of the logit model were not included because the firm's characteristics are not causal factors in forecasting a particular policy's loss ratio. The cession limit variable was retained because it is an exogenous context for the policy decision. As shown in table 4, all the variables in the Tobit model are strongly significant. The cession limit variable is positively related to the expected loss ratio suggesting higher cession limits are indicative of higher expected loss ratios in that state. The effective premium rate has a positive relationship with the expected loss ratio, and is indicative of whether the premium rate charged is a strong indicator of the observed loss ratio. There is a positive relationship between the loss ratio index and the observed loss ratio. In other words, the historical performance of a policy relative to peers producing the same crop in the same county assists in predicting the observed loss ratio. Also, county loss ratio has a positive effect. The number of actual yields used in the yield history has a negative relationship with the predicted loss ratio, suggesting that policies that have more years of actual yields are less likely to have a high loss ratio. This is not surprising given that with increased number of actual yields, the expected yield for the farm can be estimated more accurately and therefore reduce rate-setting error.

The next variable, yield span, has a positive relationship with the observed loss ratio. In general, RMA premium rates decline as the unit's APH increases relative to the base county yield. This result would suggest that perhaps the rate reduction is greater than justified by actual loss experience. Coverage level also has a positive relationship, suggesting that policies with a higher coverage level would be expected to have a higher loss ratio. This may be the result of decreasing deductibles and greater moral hazard at higher coverage levels. Net acres are shown to have a positive relationship with the observed loss ratio. In

[5] Limiting our analysis to the 2001–2003 period results in optimal cutoffs near to that of Vedenov et al (2006). We attribute this to the relatively higher loss ratios during this period as compared to the 1998–2000 period.

other words, larger farms, all else equal, tend to have slightly higher loss ratios. The number of years of continuous participation since 1994 has a positive effect, indicating that policies with more years of continuous participation have a higher loss ratio.

The next set of variables characterizes insurance design. CAT insurance is associated with a lower expected loss ratio. In other words, premiums for these policies tend to exceed indemnities over the period examined. CRC and RA policies have a higher expected loss ratio than the default yield insurance plan, while IP is less likely to have a high loss ratio. Among the crops, the expected loss ratios for wheat and soybeans tend to be higher than that of the default corn category.

Having estimated a naïve, county-level model and a more sophisticated, policy-level model to allocate policies to the Assigned Risk Fund and to estimate expected loss ratios, the implications of firm allocation decisions can be examined. This is done by applying provisions of the SRA on the outcomes of the alternative fund designation rules. We applied a simplified version of the 1998 SRA, the SRA that was in effect during the time period from which our data were drawn. We simplified the SRA by allowing policies to be placed in either the Assigned Risk Fund or in one of the three commercial funds. We also assumed, for simplification, that companies would retain 100% of the premium and associated liability on the commercial fund policies (and retain 20% of the premium and associated liability for policies in the Assigned Risk Fund, as required under the SRA).

## Comparison of Alternative Policy Assignment Strategies

Table 5 reports the aggregate underwriting gains and losses under the alternative decision rules and under the actual allocation of the crop insurance firms when applied to the out-of-sample data for 1998–2003. Under the actual allocation, companies placed $436.1 million out of a total $2,318 million (18.8%) in the Assigned Risk Fund. Over the out-of-sample observations, gross underwriting gains of policies placed in the commercial fund were $387.4 million while policies in the Assigned Risk Fund had a gross underwriting loss of $91.7 million. Total gross underwriting gains were thus $295.7 million. The gain and loss sharing under the provisions of the 1998 SRA resulted in net (post-SRA) underwriting gains of $297.8 million.

**Table 5. Underwriting Gains under Alternative Allocations to Reinsurance Funds**

| Item | Allocation | | |
|---|---|---|---|
| | Actual | County-based Model | Policy-level Model |
| | | 1,000 Dollars | |
| Gross (Pre-SRA) | | | |
| Assigned Risk Fund | | | |
| Premium | 436,084 | 135,011 | 493,378 |
| Indemnities | 527,839 | 170,474 | 667,367 |
| Gain | (91,754) | (35,463) | (173,989) |
| Commercial Funds | | | |
| Premium | 1,881,990 | 2,183,064 | 1,824,696 |
| Indemnities | 1,494,551 | 1,851,915 | 1,355,022 |
| Gain | 387,439 | 331,148 | 469,674 |
| Total Gain | 295,685 | 295,685 | 295,685 |
| Net (Post-SRA) | | | |
| Assigned Risk Fund | | | |
| Retained premium | 87,217 | 27,002 | 98,909 |
| Gain | 666 | 182 | (233) |
| Commercial Funds | | | |
| Retained premium | 1,881,990 | 2,183,064 | 1,824,696 |
| Gain | 297,165 | 289,498 | 333,836 |
| Total | | | |
| Retained premium | 1,969,207 | 2,210,066 | 1,923,605 |
| Gain | 297,831 | 289,680 | 333,603 |
| Gain as a percentage of retained premium | 15.1 | 13.1 | 17.3 |

Under the county-based model, companies would have placed a much smaller proportion of total premium in the Assigned Risk Fund, $135.1 million or 5.8%, than under the actual allocation. However, net underwriting gains under the county-based model were only $289.7 million, about $8.2 million or 2.7% less than under the actual allocation. This suggests that the current allocation used by companies is more discriminating than a model that allocates policies based on county-level performance.

Under the policy-level model, companies would have placed 21.3% of total premium in the Assigned Risk Fund ($493.4 million). Aggregate net underwriting gains for all firms would have been $333.6 million, about 12% higher under the policy-level model than under the actual allocation and 15% higher than under the county allocation model. Moreover, the more premium in the Assigned Risk Fund and less retained by the companies, increases the rate of return on retained premium. Under the policy-level model the net underwriting gains would have over 17% of retained premium, compared with about fifteen for the actual allocation and thirteen for the county-level allocation. To assess the statistical significance of the differences found here, we performed a randomized sampling within the out-of-sample data and are able confirm the differences found here are statistically significant at the 1% level. Further, we investigated whether the superior performance of the policy-level model was due to disaggregation to the policy level or due to the robustness of the explanatory variables used. An auxiliary model was estimated using the policy-level model variables aggregated to the county level. Aggregate company gains were only 1.1% less than obtained with the policy-level data. This suggests that the use of policy characteristics provides most of the additional gains rather than disaggregation.

Although the policy model improves underwriting of the companies in aggregate, its performance at the individual firm level varies. Table 6 presents proportion of premium in Assigned Risk and rates of return for the twenty-two private companies selling crop insurance

**Table 6. Percentage of Premium in Assigned Risk Fund, Loss Ratio, and Underwriting Gains under Actual, County and Policy-level Model Allocations to Reinsurance Funds, by Company**

| | Percentage of Gross Premium in Assigned Risk Fund Allocation | | | Gross Loss Ratio | Net (Post-SRA) Underwriting Gain Allocation | | |
|---|---|---|---|---|---|---|---|
| Company | Actual | County | Policy | | Actual | County | Policy |
| | Percentage of Gross Premium | | | | Percentage of Retained Premium | | |
| 1 | 21.1 | 2.3 | 8.0 | 0.88 | 18.3 | 11.6 | 15.6 |
| 2 | 15.7 | 3.5 | 18.9 | 0.80 | 18.6 | 16.1 | 21.0 |
| 3 | 32.3 | 14.8 | 34.1 | 1.05 | 6.0 | 4.3 | 9.3 |
| 4 | 1.0 | 2.0 | 0.7 | 0.65 | 26.6 | 26.3 | 27.0 |
| 5 | 42.8 | 21.6 | 56.3 | 1.35 | (12.7) | (13.0) | (6.2) |
| 6 | 26.8 | 4.2 | 21.4 | 0.91 | 11.2 | 9.2 | 13.6 |
| 7 | 15.4 | 7.4 | 25.1 | 0.94 | 10.8 | 10.1 | 12.9 |
| 8 | 19.5 | 1.8 | 11.6 | 0.62 | 24.9 | 23.7 | 26.0 |
| 9 | 24.0 | 4.3 | 24.7 | 0.86 | 21.2 | 14.2 | 20.0 |
| 10 | 22.0 | 4.2 | 17.2 | 0.78 | 21.1 | 18.1 | 21.4 |
| 11 | 32.4 | 13.2 | 41.9 | 1.22 | 3.8 | −3.7 | 5.5 |
| 12 | 11.1 | 0.0 | 2.2 | 0.33 | 35.9 | 37.2 | 37.2 |
| 13 | 2.7 | 11.9 | 6.0 | 0.65 | 22.2 | 24.5 | 24.9 |
| 14 | 21.7 | 7.8 | 29.6 | 0.99 | 10.1 | 7.4 | 13.2 |
| 15 | 18.6 | 5.0 | 17.2 | 0.94 | 8.4 | 7.1 | 9.6 |
| 16 | 9.5 | 0.6 | 8.5 | 0.49 | 26.1 | 26.7 | 27.2 |
| 17 | 27.6 | 0.3 | 1.3 | 0.34 | 37.2 | 35.3 | 38.7 |
| 18 | 2.9 | 0.1 | 2.8 | 1.10 | (0.5) | (1.0) | (0.1) |
| 19 | 17.7 | 1.2 | 7.6 | 0.58 | 27.7 | 25.6 | 26.8 |
| 20 | 32.9 | 7.1 | 17.3 | 0.76 | 23.0 | 19.2 | 24.0 |
| 21 | 13.7 | 6.7 | 22.5 | 0.95 | 12.7 | 10.3 | 14.5 |
| 22 | 19.2 | 5.3 | 18.6 | 0.85 | 15.7 | 14.7 | 19.0 |

during portions of the 1998–2003 period. While companies in aggregate placed somewhat less premium in Assigned Risk Fund under the actual than under the policy-level allocation, twelve of the twenty-two placed a larger proportion of premium in Assigned Risk Fund under the actual allocation. Net underwriting gains, as a percentage of retained premium, were highest under the policy-level allocation for nineteen of the twenty-two companies. Generally, the policy-level allocation tended to produce the highest net underwriting gain of the three methods when the gross (pre-SRA) loss ratio was high. For example, for those companies where the gross loss ratio was greater than 1.0, the policy-level allocation tended to produce the highest return. When the gross loss ratio was less than 1.0, the results were more mixed. This suggests that for firms operating primarily in states where the actuarial performance has been generally profitable (e.g., Iowa, Minnesota, and Illinois) it may be less important to discriminate between policies. In these states, the "cost" of placing business in Assigned Risk—the loss of potential underwriting gains—offsets the benefits of protecting against the risk of underwriting loss. In states where the actuarial performance is poor, however, companies may be able to improve underwriting gains by carefully discriminating between policies.

## Conclusions

With the rapid growth of the crop insurance program over the past ten years, retained premiums by companies has grown dramatically from $466 million in 1992 to almost $2.6 billion in 2003 (Glauber 2004). As companies have retained more risk, their exposure has increased proportionately. In 2003, for example, the maximum possible underwriting loss to companies was almost $2.4 billion. With increased liability and risk exposure, companies must discriminate between crop policies between those that are profitable and those that are not.

Our analysis suggests that companies incorporate available information on policyholders in allocating crop policies to the Assigned Risk Fund. Variables such as a policy's previous actuarial experience relative to peers in the county were found to be significant suggesting that companies take into account information regarding the potential profitability of a policy in making the fund allocation decision.

In general, the current allocation strategy employed by companies outperforms more simplistic strategies that allocate policies based on aggregate measures such as county loss ratios. However, our analysis also suggests that some additional underwriting profits could be gained by a more careful estimation of a policy's expected loss ratio, particularly in those states where underwriting performance is generally poor. Here, net underwriting profits can be improved or net underwriting losses can be reduced by more carefully discriminating between policies.

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